FOUCAULT'S PENDULUM EXPERIMENT.

By Torvald Köhl.

On the 17th and 20th of July I made a repetition of Foucault's pendulum experiment in the Cathedral of Roskilde, near Copenhagen, the mausoleum for the kings of Denmark. The pendulum had a length of twenty-two metres and a weight of thirty-five kilogrammes, the cylinder being of lead; the steel wire was eight-tenths of a millimeter thick.

The point of the pendulum passed through two layers of dry sand, placed on opposite sides of a circle, which was of such a size that every degree of the circumference was exactly one inch in length. The calculated deviation of one degree in each five minutes was exactly observed during more than an hour and by that time the audience had become fully convinced as to the daily motion of our restless globe.

Odder, Denmark, August 3, 1895.

NOTE ON A CAUSE OF DIFFERENCES BETWEEN DRAWINGS AND PHOTOGRAPHS OF NEBULÆ.

By James E. Keeler.

A comparison of the best drawings and photographs of nebulæ reveals at once the existence of considerable discrepancies between the forms depicted by methods so widely different. In support of this statement it is sufficient to quote the words of Dr. Roberts, who says, in briefly summing up the results of such a comparison: "All drawings alike fail to present to the eye proportions, details, and outlines as they are shown on the photographs."*

These discrepancies must no doubt be ascribed largely to the difficulty of the draftsman's task, and to certain well-recognized peculiarities of photographic action affecting the density of the silver deposit on a sensitive plate. It is found, however, that

Mon. Not. R. A. S., Vol. XLIX, page 390, (1889).

regions of equal brightness are not similarly placed on both drawings and photographs, and differences of this kind are less readily accounted for than differences of form. Now, recent researches on the spectra of the nebulæ have shown that, in at least the case of the *Orion* nebula, drawings and photographs *must* differ, for a reason which has no relation whatever to the draftsman's skill. It is more or less distinctly recognized in various papers relating to the photography of nebulæ, and is probably known to all who have followed the progress of astronomical spectroscopy, but it may not have occurred to others, and I have thought that it would be worth while to emphasize its importance in a special note.

The spectrum of the *Orion* nebula (which it will be sufficient to consider at present) consists of the two chief nebular lines $\lambda 5007$ and $\lambda 4959$, the lines of the hydrogen series, the ultra-violet line $\lambda 3727$, and a number of faint lines which need not be specially mentioned. If we compare the visual and actinic effects of these different lines, we find that a photograph on an ordinary dry-plate is practically a record of the distribution of hydrogen in the nebula, though it is modified to some extent by light emanating from unknown substances.* The image seen in the telescope, on the other hand, corresponds nearly to the distribution of the substance (or substances) yielding the two principal nebular lines, although in this case also the impression is a composite one, as the Hβ line of hydrogen is fairly bright. Roughly speaking, however, the photographic and visual images are due to light coming from different substances, and they will not agree unless these substances are distributed in the same manner in space.

Now, according to Professor CAMPBELL,† whose results I have been able to partially confirm with my inferior means, the relative intensities of the principal line and the Hβ line in the spectrum of the *Orion* nebula vary enormously; namely, from about 4:1 to about 4:20 for different parts of the nebula. We may safely take the brightness of the Hβ line as a measure of the strength of the whole hydrogen series, and as the intensity-

* According to my own photographic observations, the intensities of the lines in the Huyghenian region are related about as follows: hydrogen series, 51; (γ 3727), 7; other lines, 10.—*Astronomy and Astro-Physics*, June, 1894.

† *Publications* A. S. P., No. 32, page 206.

ratio of the two principal lines in the visual spectrum is constant,* we have in these observed facts a sufficient explanation of the differences between drawings and photographs, which form the subject of the present note.

The regions in which the Hβ line is relatively bright are, according to Professor CAMPBELL,† the fainter parts of the nebula remote from the trapezium. These regions should therefore be relatively strong on the photographs, as they are in fact.

It is interesting to note that the non-homogeneous constitution of the *Orion* nebula was suspected by Dr. HENRY DRAPER,‡ on the strength of a photograph of the spectrum taken by him in March, 1882, shortly before his death. On this photograph the ratio of intensity of the hydrogen lines Hγ and Hδ to that of two faint lines in the same region (probably λ4026 and λ4069) was not constant at all points. Had he lived, Dr. DRAPER would doubtless have investigated this subject more completely. With reference to DRAPER'S photograph of the nebula made at about the same time, Professor HOLDEN remarks in his *Monograph* that it represents the result of eye-observations more nearly than ordinary (wet) plates would do, since the plates used by Dr. DRAPER were sensitive to rays lower in the spectrum than *b*. The conclusion would be correct, if the premises were, but in the light of our present knowledge, this does not seem to be the case. DRAPER used gelatino-bromide plates, which are not sensitive below Hβ without forced exposure, and on his photographs of the spectrum (presumably) taken with the same plates, even the Hβ line did not appear.

Professor W. H. PICKERING has recently studied the constitution of the *Orion* nebula by photographing the nebula with an objective prism. § Each line in the spectrum gives a monochromatic image of the nebula. Partly on account of the overlapping of these images, and partly on account of the numerous strong star-spectra superposed on them, the results (judging by the reproduction in plate II) are somewhat less satisfactory than the beauty of the method might lead one to expect. As the lowest image in this photograph is that corresponding to the Hβ line, a direct comparison with the visual image is not possible, although

* *Publications* LICK Observatory, Vol. III, page 228.

† *Publications* A. S. P., No. 32, page 206.

‡ *American Journal of Science*, Vol. XXIII, page 340.

§ *Annals H. C. O.*, vol. 32, Part I.

Professor PICKERING points out that the great strength of the λ 3727 image in certain parts of the Huyghenian region accounts for the relatively greater brightness of these parts on an ordinary photograph of the nebula. The same method was tried by DRAPER, but with the greatly inferior arrangement of a direct-vision prism placed near the focus of the telescope.

It seems to me that an easy and satisfactory method of studying the distribution of matter in the nebula would be to photograph the nebula with an ordinary refractor (or, still better, with a reflector), with a fairly good piece of green or yellowish green glass in front of an orthochromatic plate. The glass, which should absorb practically all the light except that of the two principal nebular lines, could be tested by photographing the spectrum through it with a slit spectroscope. A photograph obtained by the above method would be directly comparable with drawings, and in case a reflector were used, it could be compared with a photograph of precisely the same dimensions taken on an ordinary plate. The exposure would be much longer than that generally required, but, according to my experience in photographing the spectrum on orthochromatic plates, it would not be excessively great. Probably the whole region covered by drawings could be obtained with such exposures as have already been given to this nebula for other purposes.

Since the curve of color sensitiveness is not the same, even for different kinds of ordinary dry plates, it follows that photographs of any non-homogeneous nebula on different plates are not strictly comparable. If plates differed greatly in this respect, it would be necessary to exercise considerable caution in comparing photographs of nebulæ for evidence of change; but, since they do not differ greatly, and since the hydrogen series is fairly well distributed over the whole range of the upper spectrum, differences in photographs owing to this cause are not likely to be appreciable.